PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 04 February 2000 (04.02.00)	
International application No. PCT/GB99/01537	**Applicant's or agent's file reference** MRH/P15101WO1
International filing date (day/month/year) 03 June 1999 (03.06.99)	**Priority date** (day/month/year) 03 June 1998 (03.06.98)
Applicant RAGINSKII, Leonid Solomonovich et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

20 December 1999 (20.12.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Jean-Marc Vivet

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

HARRISON GODDARD FOOTE
Tower House
Merrion Way
Leeds LS2 8PA
ROYAUME-UNI

Date of mailing (day/month/year)
26 July 2000 (26.07.00)

Applicant's or agent's file reference
MRH/P15101WO1

IMPORTANT NOTIFICATION

International application No.
PCT/GB99/01537

International filing date (day/month/year)
03 June 1999 (03.06.99)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

Name and Address
HARRISON GODDARD FOOTE
Belmont House
20 Wood Lane
Leeds LS6 2AE
United Kingdom

State of Nationality:
State of Residence:
Telephone No.: +44 113 2258350
Facsimile No.: +44 113 2304702
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
HARRISON GODDARD FOOTE
Tower House
Merrion Way
Leeds LS2 8PA
United Kingdom

State of Nationality:
State of Residence:
Telephone No.: +44 113 290 1400
Facsimile No.: +44 113 244 2829
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
A. Karkachi
Telephone No.: (41-22) 338.83.38

BV

ATENT COOPERATION TREAT

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
MRH/P15101WO1		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 99/ 01537	03/06/1999	03/06/1998
Applicant		
BRITISH NUCLEAR FUELS PLC et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

[ ] the text is approved as submitted by the applicant.

[X] the text has been established by this Authority to read as follows:

APPARATUS FOR DISSOLVING NUCLEAR FUEL

5. With regard to the **abstract**,

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from th date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

[ ] as suggested by the applicant.

[X] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

[ ] Non of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/01537

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G21C19/44 G21C19/38 B01F1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G21C B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SU 764 698 A (V.P. SEREBRIAKOV ET AL.) 23 September 1980 (1980-09-23) cited in the application	16-18
Y	the whole document	1-5,15, 24,25
Y	EP 0 032 070 A (COMMISSARIAT ENERGIE ATOMIQUE) 15 July 1981 (1981-07-15) the whole document	1-5,15, 24,25
A	GB 2 222 810 A (SGN SOC GEN TECH NOUVELLE ;COMMISSARIAT ENERGIE ATOMIQUE (FR)) 21 March 1990 (1990-03-21) the whole document	1,2,15, 16,24,25

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 October 1999	30/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Brothier, J-A

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/01537

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 009 868 A (ATOMIC ENERGY AUTHORITY UK) 16 April 1980 (1980-04-16) the whole document	1,16
A	FR 2 657 992 A (COMMISSARIAT ENERGIE ATOMIQUE) 9 August 1991 (1991-08-09) the whole document	1,16
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 212 (E-522), 9 July 1987 (1987-07-09) & JP 62 035531 A (FUJITSU LTD), 16 February 1987 (1987-02-16) abstract	1,16
A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 240 (M-336), 6 November 1984 (1984-11-06) & JP 59 118621 A (HITACHI SEISAKUSHO KK), 9 July 1984 (1984-07-09) abstract	1,16
A	US 3 258 852 A (R.C. WHITE) 5 July 1966 (1966-07-05) the whole document	16
A	DATABASE WPI Section Ch, Week 198233 Derwent Publications Ltd., London, GB; Class J01, AN 1982-69796E XP002120799 -& SU 874 093 A (ZAVYALOV S K), 25 October 1981 (1981-10-25) abstract; figure	1,16
A	US 4 230 675 A (YARBRO ORLAN O) 28 October 1980 (1980-10-28) cited in the application the whole document	1

2

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

[redacted]mation on patent family members

[redacted]rnational Application No
PCT/GB 99/01537

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SU 764698 A		NONE	
EP 0032070 A	15-07-1981	FR 2474469 A	31-07-1981
		CA 1162403 A	21-02-1984
		JP 1317232 C	15-05-1986
		JP 56094298 A	30-07-1981
		JP 60041319 B	14-09-1985
		US 4297324 A	27-10-1981
GB 2222810 A	21-03-1990	JP 2078997 A	19-03-1990
		JP 2740282 B	15-04-1998
EP 0009868 A	16-04-1980	GB 2027131 A,B	13-02-1980
		JP 1625663 C	18-11-1991
		JP 2048458 B	25-10-1990
		JP 55026200 A	25-02-1980
		US 4278531 A	14-07-1981
FR 2657992 A	09-08-1991	JP 5150085 A	18-06-1993
JP 62035531 A	16-02-1987	NONE	
JP 59118621 A	09-07-1984	NONE	
US 3258852 A	05-07-1966	NONE	
SU 874093 A		NONE	
US 4230675 A	28-10-1980	NONE	

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

08.AUG.2000+034121

PCT

To:

Harrison Goddard Foote
Tower House
Merrion Way
Leeds LS2 8PA
GRANDE BRETAGNE

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	-4. 08. 00

Applicant's or agent's file reference	IMPORTANT NOTIFICATION
MRH/P15101WO1	

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/01537	03/06/1999	03/06/1998

Applicant
BRITISH NUCLEAR FUELS PLC et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international applicatio

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of th report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation mus contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Schuster-Kaechele, W Tel.+49 89 2399-2281

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
MRH/P15101WO1		

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/01537	03/06/1999	03/06/1998

International Patent Classification (IPC) or national classification and IPC
G21C19/44

Applicant
BRITISH NUCLEAR FUELS PLC et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authorit and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/12/1999	04.08.00

Nam and mailing address of the international preliminary examining authority:	Authoriz d officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Frisch, K Telephone No. +49 89 2399 2559

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/015

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Offi response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed the report since they do not contain amendments.*):

Description, pages:

1-10	as originally filed				

Claims, No.:

1-25	as received on	13/07/2000	with letter of	10/07/2000	

Drawings, sheets:

1/3-3/3	as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have b considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to nov lty, inventiv step or industrial appli ability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-25
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-25
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-25
	No:	Claims	

2. Citations and explanations

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Concerning Part V: Novelty, Inventive step, Industrial applicability:

The document D1=SU-A-764.698 (figures 1 and 2), which is deemed to represent the closest prior art, discloses an apparatus comprising a perforated sloping ramp (7) contained within a chamber (1), and a pulsation means (5) which can create pulses in a liquid contained in the chamber, the ramp perforations being such that they can direct pulses of the liquid up and along the ramp. The apparatus has a discharge point at an upper region of the ramp. Although D1 apparently does not explicitly state that this apparatus is to be used in connection with a nuclear fuel dissolution process, it appears, contrary to the statements in the present description (page 3, lines 4-8), that it would indeed be suitable for such a use. In such use, the chamber should merely be filled with nitric acid (or another solvent) and pieces of nuclear fuel pins. It is noted that the fuel pin pieces might have to be smaller or otherwise differently prepared than those mentioned on page 3 of the present description, but this does not make the prior art apparatus of D1 generally unsuitable for fuel dissolution processes. In fact, D1 does not appear to state any feature which would disqualify the apparatus for use in a nuclear fuel dissolution process. The apparatus of D1 can therefore also be referred to as a "nuclear fuel dissolution apparatus" as in present claim 1, since this expression means merely that the apparatus could be used for dissolving nuclear fuel. It follows that D1 discloses all the features stated in the preamble of present claim 1.

Similarly, D1 also discloses the features stated in the preamble of present claim 15: The apparatus disclosed in D1 may serve to treat solid articles by liquid, and it comprises a container of circular cross section, a helical ramp in the container and a pulsator communicating with a lower part of the container. The container has connections suitable for feeding in and removing fuel pin pieces, liquid and gas.

D1 does not appear to state that the ramp is made out of flat blades or that the ramp perforations comprise inclined slits formed between the blades, as stated in each of present claims 1 and 15. The apparatus defined in these claims is therefore deemed to be new over the prior art of D1 (Article 33.2 PCT).

Since none of the other documents mentioned in the international search report relates to a similar apparatus having a ramp made of flat blades forming inclined slits there between, and since such a ramp is not considered to be obvious in itself, the apparatus defined in each of claims 1 and 15 as well as the use of such an apparatus according to claim 23 are also deemed to involve an inventive step within the meaning of Article 33.3 PCT.

Claims 2-14, 16-22 and 24-25 are proper dependent claims referring back to claims 1, 15 or 23. The subject-matter defined in these claims is therefore also deemed to be new and inventive over the available prior art.

Concerning Part VIII; Clarity, Conciseness (Article 6 PCT):

The various definitions of the invention given in independent claims 1 and 15 include numerous repetitions of technical features. The dependent claims 16-22 and 24 also repeat features already stated in earlier claims. The set of claims is therefore not concise. The independent claims 1 and 15 also have overlapping scopes, each of these claims including features not found in the other independent claims, thereby making it uncertain which features are essential to the invention. Consequently, it is uncertain whether any one of the independent claims includes all essential features of the invention (PCT Guidelines, III-4.4).

In claims 8 and 11 parameters of the apparatus are defined in terms of the diameter of a fuel pin. Since this diameter is undefined and external to the claimed apparatus, the scope of these claims is not clear. In claim 11 the reference to earlier claims is incomplete. The additional method step stated in claim 14 does not in clear terms imply any structural limitation for the apparatus defined in the claim. In claim 14 it is furthermore not clear what is meant by the reference to "an apparatus ... which is performed ...".

The description has not been brought into conformity with the present claims, and it does not clearly state the object or advantage of the invention relative to the prior art of D1 (Rule 5.1.a.ii PCT).

REVISED CLAIMS

1. A nuclear fuel dissolution apparatus which comprises a perforated sloping ramp (19) contained within a process chamber (1) for containing solvent for the fuel, a pulsation member (9) which in use creates pulses in solvent in the process chamber (1), the perforations (7) being designed to direct pulses of solvent along and up the ramp (19), and a discharge point (18) for fuel hulls disposed at an upper region of the ramp characterised in that the ramp (19) is made out of flat blades (6) and the perforations (7) of the ramp (19) comprise inclined slits formed between the blades (6).

2. An apparatus of claim 1 in which the ramp (19) is spiral.

3. An apparatus of claim 1 or claim 2 in which the process chamber (1) has an outer side wall which is circular in cross section.

4. An apparatus of any of claims 1 to 3 in which the gradient of the spiral is between 1 and 30 degrees.

5. An apparatus of claim 4 in which the gradient is between 1 and 20 degrees.

6. An apparatus of any of claims 1 to 5 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

7. An apparatus of claim 1 in which the angle between the plane of the blades and the horizontal is between 10 and 60 degrees.

8. An apparatus of claim 1 or claim 7 in which the inclined slits are no more than 10 fuel pin diameters in length.

9. An apparatus of claim 1 in which the blades (6) are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber (1).

10. An apparatus of claims 1 in which the average width of the blades (6) is between 3 and 5 times the distances between them.

11. An apparatus of claim in which the distance between the plates at the outside wall of the container is 0.4 to 0.8 times the fuel pin diameter.

12 An apparatus of claim 1 in which the pulsation member (9) comprises a pulsation chamber disposed centrally within the process chamber (1).

13 An apparatus of claim 12 in which a neutron absorber is arranged between the pulsation chamber (1) and an inside wall of the annular container.

14. An apparatus of any of claims 1 to 13 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

15. An apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp (19) located in the container, and a pulsator (9) communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp (19) is made up of flat blades (6) placed one after another along the spiral and forming between one another inclined slit nozzles and the perforations (7) of the ramp comprise inclined slits between the blades (6).

16. An apparatus of claim 15 in which the gradient of the spiral is between 1 and 30 degrees.

17. An apparatus of claim 16 in which the gradient is between 1 and 20 degrees.

18. An apparatus of any of claims 15 to 17 in which the angle between the plane of the blades and the horizontal plane is between 15 and 60 degrees.

19. An apparatus of any of claims 15 to 18 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

20. An apparatus of any of claims 15 to 19 in which the blades (6) are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber (1).

21. An apparatus of any of claims 15 to 20 in which the average width of the blades is between 3 and 5 times the distances between them.

22. An apparatus of any of claims 15 to 21 in which the pulsation member comprises a pulsation chamber (9) disposed coaxially within the process chamber (1).

23. A method of dissolving fuel in chopped nuclear fuel pins in an apparatus according to claim 1.

24. A method according to claim 23 wherein the apparatus comprises a perforated sloping ramp (19) contained within a process chamber (1) for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber (1), the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process chamber (1), loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp.

25. A method of claim 23 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
MRH/P15101WO1		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/01537	03/06/1999	03/06/1998
International Patent Classification (IPC) or national classification and IPC G21C19/44		
Applicant BRITISH NUCLEAR FUELS PLC et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Auth rity (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 3 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
20/12/1999	14. 08. 00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Frisch, K Telephone No. +49 89 2399 2559

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/01537

I. Basis of the r port

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-10	as originally filed			

Claims, No.:

1-25	as received on	13/07/2000	with letter of	10/07/2000

Drawings, sheets:

1/3-3/3	as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims 1-25
	No:	Claims
Inventive step (IS)	Yes:	Claims 1-25
	No:	Claims
Industrial applicability (IA)	Yes:	Claims 1-25
	No:	Claims

2. Citations and explanations

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Concerning Part V; Novelty, Inventive step, Industrial applicability:

The document D1=SU-A-764.698 (figures 1 and 2), which is deemed to represent the closest prior art, discloses an apparatus comprising a perforated sloping ramp (7) contained within a chamber (1), and a pulsation means (5) which can create pulses in a liquid contained in the chamber, the ramp perforations being such that they can direct pulses of the liquid up and along the ramp. The apparatus has a discharge point at an upper region of the ramp. Although D1 apparently does not explicitly state that this apparatus is to be used in connection with a nuclear fuel dissolution process, it appears, contrary to the statements in the present description (page 3, lines 4-8), that it would indeed be suitable for such a use. In such use, the chamber should merely be filled with nitric acid (or another solvent) and pieces of nuclear fuel pins. It is noted that the fuel pin pieces might have to be smaller or otherwise differently prepared than those mentioned on page 3 of the present description, but this does not make the prior art apparatus of D1 generally unsuitable for fuel dissolution processes. In fact, D1 does not appear to state any feature which would disqualify the apparatus for use in a nuclear fuel dissolution process. The apparatus of D1 can therefore also be referred to as a "nuclear fuel dissolution apparatus" as in present claim 1, since this expression means merely that the apparatus could be used for dissolving nuclear fuel. It follows that D1 discloses all the features stated in the preamble of present claim 1.

Similarly, D1 also discloses the features stated in the preamble of present claim 15: The apparatus disclosed in D1 may serve to treat solid articles by liquid, and it comprises a container of circular cross section, a helical ramp in the container and a pulsator communicating with a lower part of the container. The container has connections suitable for feeding in and removing fuel pin pieces, liquid and gas.

D1 does not appear to state that the ramp is made out of flat blades or that the ramp perforations comprise inclined slits formed between the blades, as stated in each of present claims 1 and 15. The apparatus defined in these claims is therefore deemed to be new over the prior art of D1 (Article 33.2 PCT).

Since none of the other documents mentioned in the international search report relates to a similar apparatus having a ramp made of flat blades forming inclined slits there between, and since such a ramp is not considered to be obvious in itself, the apparatus defined in each of claims 1 and 15 as well as the use of such an apparatus according to claim 23 are also deemed to involve an inventive step within the meaning of Article 33.3 PCT.

Claims 2-14, 16-22 and 24-25 are proper dependent claims referring back to claims 1, 15 or 23. The subject-matter defined in these claims is therefore also deemed to be new and inventive over the available prior art.

Concerning Part VIII; Clarity, Conciseness (Article 6 PCT):

The various definitions of the invention given in independent claims 1 and 15 include numerous repetitions of technical features. The dependent claims 16-22 and 24 also repeat features already stated in earlier claims. The set of claims is therefore not concise. The independent claims 1 and 15 also have overlapping scopes, each of these claims including features not found in the other independent claims, thereby making it uncertain which features are essential to the invention. Consequently, it is uncertain whether any one of the independent claims includes all essential features of the invention (PCT Guidelines, III-4.4).

In claims 8 and 11 parameters of the apparatus are defined in terms of the diameter of a fuel pin. Since this diameter is undefined and external to the claimed apparatus, the scope of these claims is not clear. In claim 11 the reference to earlier claims is incomplete. The additional method step stated in claim 14 does not in clear terms imply any structural limitation for the apparatus defined in the claim. In claim 14 it is furthermore not clear what is meant by the reference to "an apparatus ... which is performed ...".

The description has not been brought into conformity with the present claims, and it does not clearly state the object or advantage of the invention relative to the prior art of D1 (Rule 5.1.a.ii PCT).

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G21C 19/44, 19/38, B01F 1/00

A2

(11) International Publication Number: WO 99/63545

(43) International Publication Date: 9 December 1999 (09.12.99)

(21) International Application Number: PCT/GB99/01537

(22) International Filing Date: 3 June 1999 (03.06.99)

(30) Priority Data:
98110181 3 June 1998 (03.06.98) RU

(71) Applicant *(for all designated States except US)*: BRITISH NUCLEAR FUELS PLC [GB/GB]; Risley, Warrington, Cheshire WA3 6AS (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: RAGINSKII, Leonid Solomonovich [RU/RU]; ul. Marshala Vershinina, 4–2–8, Moscow, 123060 (RU). MORKOVNIKOV, Vyacheslav Evgen'evich [RU/RU]; ul. Zemlyanoi val, 52/16–156, Moscow, 109240 (RU). MOROZOV, Nikolai Viktorovich [RU/RU]; Rublevskoe shosse, 15–47, Moscow, 121108 (RU). ELISEEV, Sergei Petrovich [RU/RU]; Novye Cheremushki, kvartal, 32–a–4–7, Moscow, 113461 (RU). RANCE, Peter [GB/GB]; 33 Main Street, St Bees, Cumbria CA27 0AA (GB). TINSLEY, Timothy [GB/GB]; 14 Red Beck Park, Cleator Moor, Cumbria CA25 5EX (GB). DENNISS, Iain [GB/GB]; 14 Westfield Drive, Egremont, Cumbria CA22 2JJ (GB).

(74) Agent: HARRISON GODDARD FOOTE; Belmont House, 20 Wood Lane, Leeds LS6 2AE (GB).

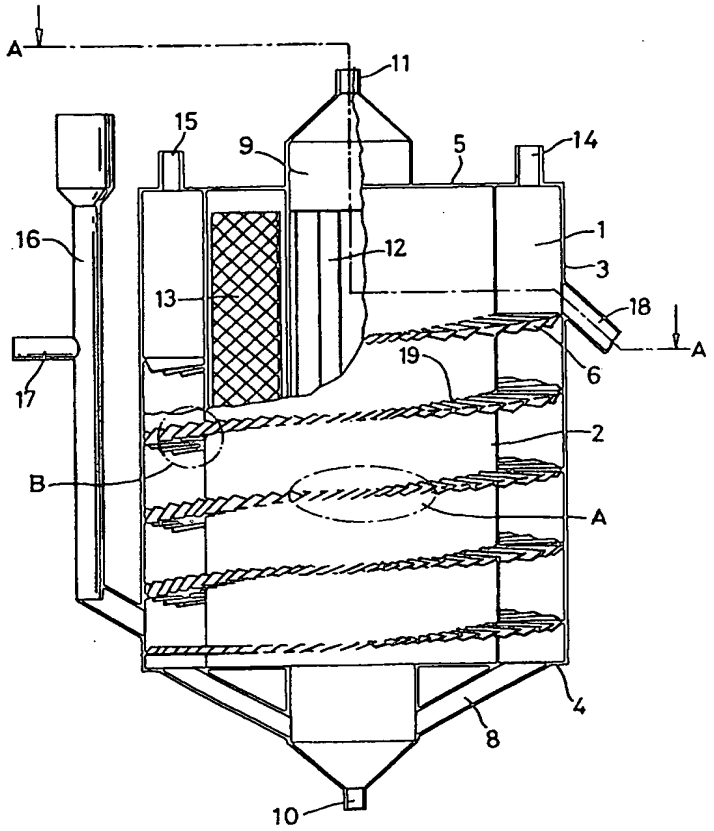
(81) Designated States: CA, CN, JP, KR, RU, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: APPARATUS FOR DISSOLVING NUCLEAR FUEL

(57) Abstract

Nuclear fuel dissolution apparatus comprises a perforated sloping ramp (6) located within a process chamber (1). A pulsation member creates pulses in the solvent in the container, and the perforations of the sloping ramp are designed to direct pulses of solvent along and up the ramp. A discharge point (17, 18) for fuel holes is disposed at an upper region of the ramp. A method of dissolving fuel in chopped nuclear fuel pins is also described.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

APPARATUS FOR DISSOLVING NUCLEAR FUEL

The present invention relates to the reprocessing of irradiated nuclear fuel and particularly the dissolution of nuclear fuel pins.

Nuclear fuel pins consist of pellets of fissile material, e.g. UO_2, contained in a cladding which is normally a zirconium alloy sold under the trade mark Zircaloy. A cluster of pins form a fuel assembly.

Commercial reprocessing of irradiated (spent) nuclear fuel uses the Purex process, which involves chopping up the pins of an assembly prior to dissolution of the fissile material in nitric acid. The pins must be chopped up to expose the pellets to nitric acid because the bulk zirconium alloy is resistant to attack by nitric acid, as is an oxide skin which irradiated zirconium alloy possesses. After the fuel has been dissolved the empty pieces of cladding (hulls) and other residues of the structure of the fuel assembly are encapsulated and disposed of.

Commercial reprocessing plants contain dissolvers based on one of two principles: batch operation or continuous operation using an apparatus with rotating mechanical parts.

In a typical batch dissolver the fuel is sheared into a large basket which is immersed in the dissolver vessel. After the fuel has been leached, the basket is removed from the dissolver using a crane and then tipped to transfer the hulls and other debris to the encapsulation plant. This system requires extensive mechanical handling of the dissolver basket which is heavy and needs a large amount of maintainable equipment in the shielded dissolver cell.

Continuous dissolvers shear the fuel into the segments of a wheel which is rotated inside a large vessel. The existence of rotating parts is a disadvantage and limits the geometry that can be adopted to a very large slab tank if the equipment is ever to be safe.

US 4246238 discloses a batch action apparatus comprising a container in which is placed a basket filled with pieces of fuel pins, and to which pipe connections are fitted to feed in and remove solutions and gas. A disadvantage of the apparatus is the complexity of the sealing arrangement when the fuel pin pieces are loaded into the basket and when baskets are discharged from the apparatus, as well as the difficulty of containing radioactivity. In addition, use of such apparatuses would considerably complicate process automation and increase the volumes of radioactive solutions.

US 4230675 discloses an apparatus which is used to make countercurrent contact between fuel pin pieces and leaching solution. The apparatus comprises an elongate cylindrical drum which rotates around its longitudinal axis and is divided by transverse partitions into a chamber for feeding in fuel pin pieces and removing solution situated at one end of the drum, and a chamber for exit of the cladding pieces and delivery of solution situated at the other end of the drum. Between these chambers there are several other chambers in which leaching of the fuel from the chopped cladding takes place. In each chamber there are elements which provide for movement of the fuel pin pieces on rotation of the drum. A disadvantage of the apparatus is the complexity of its design, and the presence of moving units and of units subject to intensive abrasive action caused by the fuel pin pieces. An apparatus of this design would therefore have a low level of reliability and require regular servicing and maintenance under conditions of high levels of radioactive contamination.

Moving away now from nuclear reprocessing, USSR author's certificate No 764698 discloses a mass-exchange device for solid phase treatment (primarily for the treatment of wood chips) which comprises a cylindrical casing inside which is a perforated helical ramp with a helical surface gradient of between 4 and 30 degrees. The perforations are in the form of apertures screened above and below by angled plates. Some of the apertures are fitted with nozzles protruding above the surface of the ramp. In a bottom part of the apparatus, which is separated from the annular container by a grid, there is a pulse generator. In use, solid particles are charged onto the ramp at its bottom end. Pulsed fluid from the pulse generator passes upwards through the apertures in the ramp and raises the solid particles above the ramp, creating a pulsing suspended layer in which the particles

are processed by the fluid. The solid particles are moved upwards and discharged at the top of the ramp.

The apparatus of USSR author's certificate No 764698 could not be used with chopped nuclear fuel pins and is incompatible with a nuclear reprocessing plant. Amongst other things, chopped fuel pins have a diameter of between 8 and 20 mm, a length of between 25 and 100 mm and a weight of up to 70 g and would not be moved up the ramp of the apparatus as described

A pulsation device which is designed for dissolving nuclear fuel pins is known from EP-A-358354 which comprises a V-shaped duct connected to a pulsation chamber containing nitric acid. Pieces of chopped fuel pin are loaded into the free end of one arm of the V-shaped duct. Compressed air in the pulsation chamber maintains nitric acid in the duct at a level which immerses most of the chopped pieces. The air pressure in the pulsation chamber is periodically released, resulting in most of the nitric acid in the duct leaving it. Compressed air is then again applied to the nitric acid in the pulsation chamber, causing acid to pulse into the duct such that leached hulls in the outlet arm of the duct are pushed upward to a discharge duct through which they leave the V-shaped duct.

An advantage of this apparatus is the simplicity of its design and the absence of moving parts. A disadvantage of the apparatus is the small volume of its process chamber and the low output of a single unit, with pieces of fuel pin spending a long time in the apparatus, as is essential for dissolution of the fuel. This is because the diameter of the V-shaped duct is restricted for criticality reasons, and the depth of the layer of fuel pin pieces in the duct is limited by the requirement that the pieces must move along steadily in a curving duct. To ensure that the required time is spent by the fuel pin pieces in the solution, therefore, a cascade of apparatuses of this type installed one after the other in sequence would have to be used. This would considerably complicate the apparatus layout, reduce the reliability of the equipment and also substantially increase the dimensions of the process areas.

The problem on which a first aspect of the invention is based, therefore, is to provide apparatus for use in the dissolution of nuclear fuel pins in which the apparatus can reliably be used to dissolve fuel contained in chopped cladding and to discharge hulls from the dissolver as well as require little maintenance and servicing, and which would not require a complicated apparatus layout or an excessive process area in the reprocessing plant.

The present invention provides a nuclear fuel dissolution apparatus comprising a perforated sloping ramp contained within a process chamber for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, and a method comprising loading solvent into the process chamber, loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp.

In preferred apparatus the ramp is spiral; the gradient of the spiral is preferably between 1 and 30 degrees and more usually between 1 and 20 degrees. Preferably, the process chamber is annular in cross section.

The gradient of the spiral in an upper zone of the process chamber may be greater than in a lower zone.

It is most preferred that the ramp is made out of flat blades, in which case the perforations of the ramp comprise inclined slits formed between the blades.

Preferably the angle between the plane of the blades and the horizontal is between 10 and 60 degrees.

In practice, the apparatus must be designed to have a so-called "eversafe geometry", that is, to avoid a critical mass of material collecting which allows a self-sustaining fission reaction. For this reason, the apparatus will in practice be designed to control the total amount of fissile material which can accumulate in any one place and/or the geometry in

which such accumulated fissile material is held. It is preferred for criticality reasons for the fissile material (chopped fuel pins) to be in elongate form rather than spherical In a particular version of the method, each pair of adjacent blades makes a slit having a length (the dimension in the radial direction in the case of a spiral ramp in an annular chamber) of no more than 10 times the diameter of a fuel pin; such a design helps avoid an excessive accumulation of chopped fuel pins in the slit. More preferably, the slit length is between 5 and 10 times the diameter of a fuel pin.

In some embodiments the blades are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber.

Preferred apparatus involves one or both of the features that the average width of the blades (extent of slit channel) is between 3 and 5 times the distances between them and that the distance between the plates at the outside wall of the container is 0.4 to 0.8 times the fuel pin diameter.

Preferably, the pulsation member comprises a pulsation chamber located coaxially within the process chamber. Normally, a neutron absorber is arranged between the pulsation chamber and an inside wall of the annular container.

In a particular version of the invention, the pulsation chamber, usually made in the shape of a cylindrical container, is located coaxially within the process chamber (which is usually annular) and communicates with a lower part of the process chamber by a an upwardly and outwardly directed duct (usually an annular slit). In preferred classes of the invention, a neutron absorber is situated between the pulsation chamber and an inside wall of the annular container.

The invention in another aspect provides an apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp located in the container, and a pulsator communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp is made up of flat blades placed one after

another along the spiral and forming between one another inclined slit nozzles. Such apparatus is particularly suitable for the chemical treatment of solid phase articles larger or heavier than the wood chips with which is concerned the prior art spiral pulsed fluid apparatus.

Usually, the process chamber of either aspect has an inner side wall as well as the inevitable outer side wall. The ramp in such chambers normally extends between the inner and outer side walls of the process chamber

The present invention also provides a method of dissolving fuel in chopped nuclear fuel pins in an apparatus comprising a perforated sloping ramp contained within a process chamber for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process chamber, loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp. The method may be performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

The present invention is further described below by way of example only with reference to apparatus for dissolving the spent fuel of chopped fuel pins. It will be understood, however, that the invention may be applied to the fluid treatment of solids other than fuel pin pieces. The apparatus is illustrated non-limitatively by the accompanying drawings, in which:

Fig. 1 gives a general view of the apparatus for dissolution showing a cross-section and the appearance of the ramp made up of blades fitted one after the other along the spiral;

Fig. 2 shows a cross-section of the apparatus along line A-A of Fig. 1;

Fig. 3 is an enlarged view of fragment A in Fig. 1 of the internal cylindrical shell of the annular container of the apparatus with ramp blades fitted on it;

Fig. 4 shows fragment B of the ramp from Fig. 1;

Fig. 5 shows fragment C of the ramp from Fig. 2; and

Fig. 6 shows the shape of the blades in the form of a rectangular (a) and isosceles (b) trapezium.

Fig. 1, therefore, illustrates a nuclear fuel dissolution apparatus which comprises a perforated sloping ramp (19) contained within a process chamber(1) for containing solvent for the fuel, a pulsation member (9) which in use creates pulses in solvent in the process chamber (1), the perforations (7) being designed to direct pulses of solvent along and up the ramp (19), and a discharge point (18) for fuel hulls disposed at an upper region of the ramp.

More particularly, the apparatus shown is for leaching of fuel in fuel pin pieces and comprises an annular reaction container (1), formed by internal (2) and external (3) cylindrical shells, and also a drain (4) and a cover (5). In the annular container (1) are blades (6) fitted one after another along a spiral between the internal (2) and external (3) walls of the container at a distance not exceeding the diameter of the fuel pin. (It will be appreciated that an apparatus of the invention cannot be used to treat articles able to fall between the blades (6)).

The blades form a spiral ramp for upwards movement of pieces of fuel pin upon pulsation of solvent (nitric acid in the Purex process) in the annular container (1). Each pair of adjacent blades (6) (see Fig. 3) forms an inclined slit nozzle (7). The gradient "α"of the spiral is between 1 and 20 degrees, and the angle "β" between the plane of the blades and the horizontal surface is between 15 and 60 degrees.

The annular container (1) (see Fig. 1) communicates, in this case through an inclined conical slit (8) and the drain (4), with a pulsation chamber (9). In the illustrated embodiment the pulsation chamber is cylindrical and is situated coaxially with the annular container (1); it is equipped in its lower part with an outlet, normally a pipe connection (10), to empty the apparatus. The pulsation chamber (9) communicates, in this case via a pipe connection (11), with a pneumatic pulsator (not shown in Fig. 1), and a plate damping device (12) or other damping device is situated inside the chamber to ensure that

liquid in the chamber moves without waves or splashing. In the annular gap between the container (1) and the pulsation chamber (9) is a neutron absorber (13) to ensure nuclear safety while nuclear fuel leaching is going on. The neutron absorber (13) is of course dispensed with in non-nuclear applications.

Suitable fluid inlets and outlets are provided for treatment liquid and for gas. Thus, the illustrated apparatus includes pipe connections to feed in solution (14) and blow off gases (15) connected to the upper part of the annular container (1). An inlet for the solid phase material (in this case pipe connection (16) to feed in pieces of fuel pin with nuclear fuel) is connected to the lower part of the annular container (1). A pipe connection (17) is connected to pipe connection (16) to remove solution from the leaching apparatus; alternatively another solution outlet may be provided. A discharge point is provided for the discharge of fuel hulls from the top of the ramp (19); specifically, a pipe connection (18) is connected to an upper part of the container (1) to remove the tubular fuel hulls after dissolution of the fuel

In one embodiment of the pulsation apparatus, the gradient of the spiral in an upper part of the annular container (1) is greater than in a lower part. Thus, for example, the gradient of the spiral in the lower and middle parts of the apparatus may be set at 2 degrees, and in the upper part at 4 degrees. This enables the time spent by the pieces in the apparatus to be extended for fuel pin pieces in which, for one or another reason, there has not been full leaching of the fuel. Since such pieces are of greater mass, an increase in the gradient of the spiral leads to a slowing of their movement towards the zone of discharge from the apparatus.

In another embodiment, the blades (6) (see Fig. 6) are made in the form of a trapezium and are fastened by their smaller end on the inside wall (2) of the annular container (1). This enables the optimum angle of the guide surface of the helical ramp towards the axis of symmetry of the apparatus to be obtained to compensate for centrifugal forces on the fuel pin pieces when the pulsation jets act on them to be compensated.

In another version of the invention, the width of the blades (6) is between 3 and 5 times the distances between them. This enables flat jets of the liquid phase to be formed with pulsation of liquid in the annular container, to move the layer of fuel pin pieces upwards along the spiral guide ramp. Irrespective of the blade width, the distance between the blades (6) at the outside wall of the container is suitably 0.4-0.8 times the external diameter of the fuel pin. This ratio of sizes prevents blockage of the slits by fuel pin pieces, and reduces the hydraulic resistance of the apparatus and pulsation energy losses.

The apparatus operates as follows. The annular container (1) and the pulsation chamber (9) are filled with fuel leaching solution, which comes in through the pipe connection (14). The feed of sheared fuel pin pieces, which takes place over a set time, is via the pipe connection (16) onto the lower section of the spiral ramp formed by the blades (6). Pneumatic pulses from the pulsator (not shown in the Figures), which have set parameters for gas pressure, frequency and shape of oscillations along the pipe (11) (see Fig. 1), enter the pulsation chamber (9). Under the influence of these pulses, the solution filling the pulsation chamber (9) and the annular container (1) moves in an oscillating (reciprocal) fashion at a set frequency, amplitude and pulsation shape. The level damper (12) which is in the pulsation chamber (9) ensures that the solution moves without waves or splashing.

These oscillations are transferred via the slit channel (8) to the solution in the annular container (1). Passing through the slit nozzles (7) formed by the blades (6) (see Fig. 3) of the spiral ramp, the solution forms flat pulsation jets. When the solution in the annular container (1) moves upwards under the influence of these jets, the fuel pin pieces are taken away from the surface of the spiral ramp formed by the blades (6) and move along and up it by a certain distance. When the compressed gas is released from the pulsation chamber (9) into the blow-off, the solution in the annular container (1) moves downwards through the static difference in levels in the annular container (1) and the pulsation chamber (9). This makes the solution press the fuel pin pieces to the blades (6) of the ramp, and they move no further along the ramp until the next pulse. In subsequent pulsation cycles, the process is repeated and the fuel pin pieces gradually move along the spiral ramp in an upward direction. Moving along the spiral ramp, the fuel pin pieces

gradually rise upwards through the apparatus and at the end of the ramp they pass out of the apparatus via the pipe connection (18), along with a certain quantity of solution.

Fresh solution entering the annular container (1) via the pipe connection (14), moves towards the fuel pin pieces, dissolving the fuel contained in them, and leaves the apparatus through a pipe connection (17), which is connected to the loading channel (16). To remove gases formed during the process of spent fuel dissolution, a blow-off pipe is provided on the cover (5) of the annular container (1). As the fuel dissolves in the fuel pin pieces, their mass diminishes, and their rate of movement along the ramp rises. To reduce the rate of movement of the fuel pin pieces in which fuel still remains, the design of the apparatus envisages an increase in the gradient of the spiral ramp in the upper part of the apparatus.

The invention in preferred embodiments provides pulsation apparatus having the combination of spatial and geometric characteristics which will give the most effective hydrodynamic conditions for stable movement of pieces of sheared fuel pin up the spiral in the annular space with fuel pieces having a length to diameter ratio of between 1:1 and 6:1 while preventing criticality in the apparatus and giving it a high output

The method of the invention is typically performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

In another embodiment of apparatus in accordance with the present invention, the welded together blades of the above described embodiment are replaced by a single plate having transverse elongate slots located therein.

CLAIMS

1. A nuclear fuel dissolution apparatus which comprises a perforated sloping ramp contained within a process chamber for containing solvent for the fuel, a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, and a discharge point for fuel hulls disposed at an upper region of the ramp.

2. An apparatus of claim 1 in which the ramp is spiral.

3. An apparatus of claim 1 or claim 2 in which the process chamber has an outer side wall which is circular in cross section.

4. An apparatus of any of claims 1 to 3 in which the gradient of the spiral is between 1 and 30 degrees.

5. An apparatus of claim 4 in which the gradient is between 1 and 20 degrees.

6. An apparatus of any of claims 1 to 5 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

7. An apparatus of any of claims 1 to 6 in which the ramp is made out of flat blades and the perforations of the ramp comprise inclined slits formed between the blades.

8. An apparatus of claim 7 in which the angle between the plane of the blades and the horizontal is between 10 and 60 degrees.

9. An apparatus of claim 7 or claim 8 in which the inclined slits are no more than 10 fuel pin diameters in length.

10. An apparatus of any of claims 7 to 9 in which the blades are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber.

11. An apparatus of any of claims 7 to 10 in which the average width of the blades is between 3 and 5 times the distances between them.

12. An apparatus of any of claims 7 to 11 in which the distance between the plates at the outside wall of the container is 0.4 to 0.8 times the fuel pin diameter.

13. An apparatus of any of claims 1 to 12 in which the pulsation member comprises a pulsation chamber disposed centrally within the process chamber.

14. An apparatus of claim 13 in which a neutron absorber is arranged between the pulsation chamber and an inside wall of the annular container.

15. An apparatus of any of claims 1 to 14 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

16. An apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp located in the container, and a pulsator communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp is made up of flat blades placed one after another along the spiral and forming between one another inclined slit nozzles.

17. An apparatus of claim 16 in which the gradient of the spiral is between 1 and 30 degrees.

18. An apparatus of claim 17 in which the gradient is between 1 and 20 degrees.

19. An apparatus of any of claims 16 to 18 in which the angle between the plane of the blades and the horizontal plane is between 15 and 60 degrees.

20. An apparatus of any of claims 16 to 19 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

21. An apparatus of any of claims 16 to 20 in which the blades are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber.

22. An apparatus of any of claims 16 to 21 in which the average width of the blades is between 3 and 5 times the distances between them.

23. An apparatus of any of claims 16 to 22 in which the pulsation member comprises a pulsation chamber disposed coaxially within the process chamber.

24. A method of dissolving fuel in chopped nuclear fuel pins in an apparatus comprising a perforated sloping ramp contained within a process chamber for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process chamber, loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp.

25. A method of claim 24 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

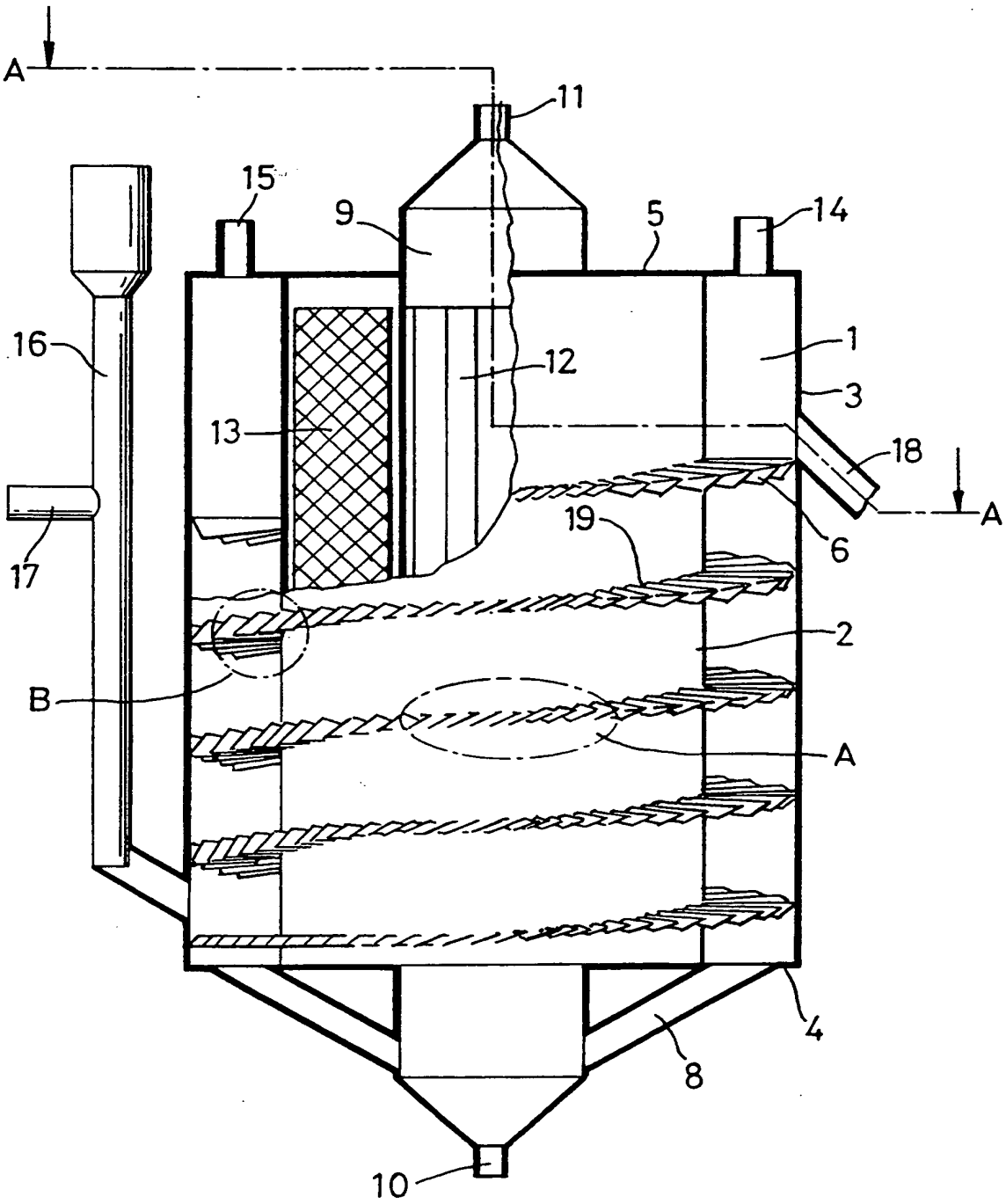


Fig. 1

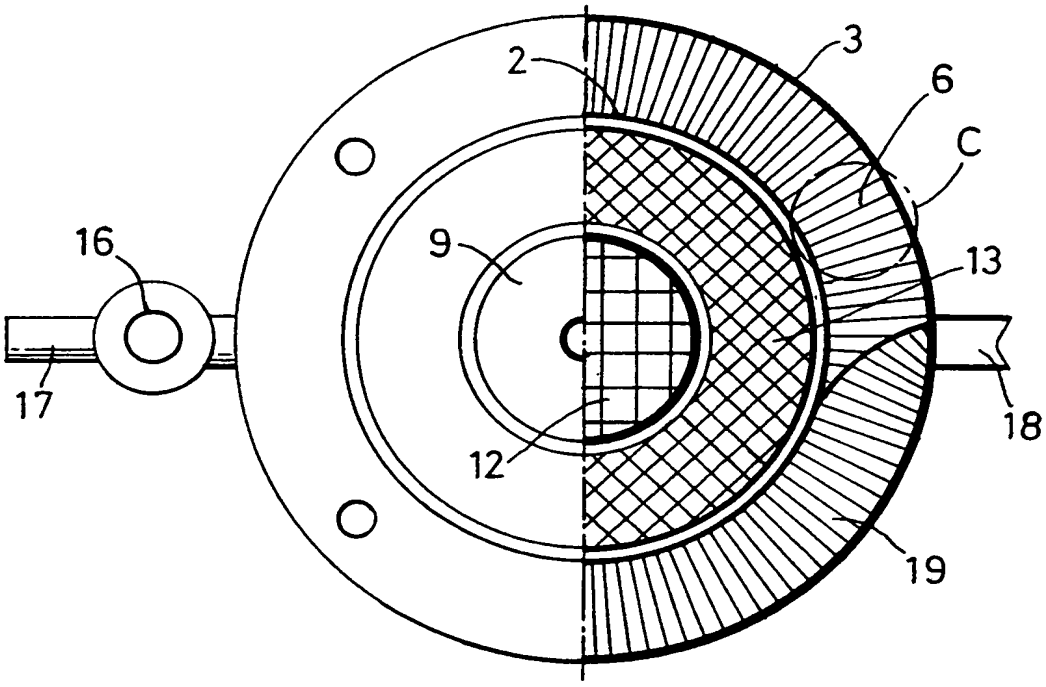


Fig. 2

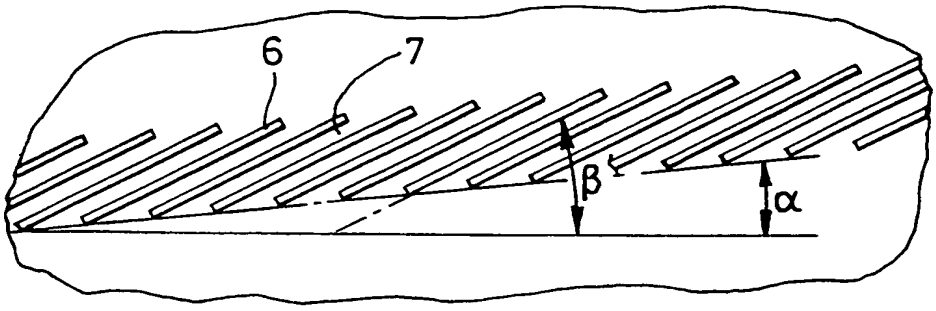


Fig. 3

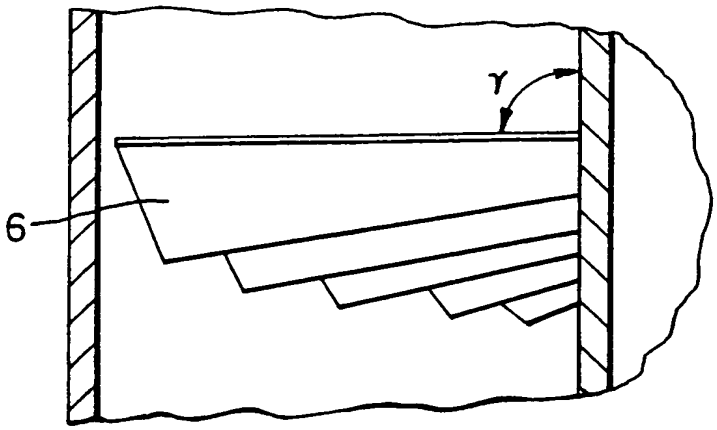


Fig. 4

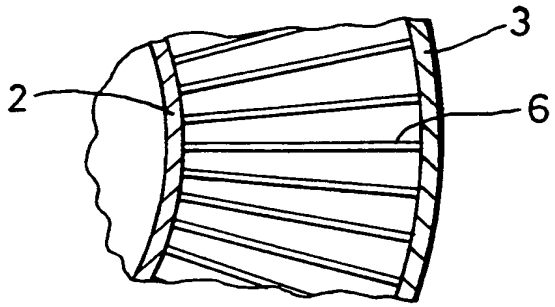


Fig. 5

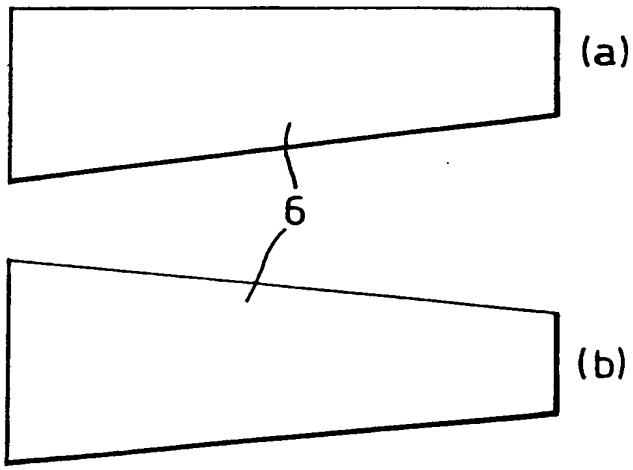


Fig. 6